

# Research on Integrated Energy Trading Mechanism Based on Blockchain Smart Contract Technology

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**Abstract**—With the development of integrated energy services, the number, scale and information data of multi-energy transactions increase sharply, the time and material costs of energy transactions become higher, and users have higher requirements for the fairness, transparency and privacy of transactions. As a decentralized distributed accounting system, blockchain is characterized by traceability, security, credibility and non-tampering of transactions, which can meet the needs of integrated energy and multi-energy transactions. Based on the research on the application of blockchain technology in the field of integrated energy services, this paper proposes a integrated energy trading process based on smart contract, launches a new trading mode of "Energy Package", and explores the application of blockchain technology in integrated energy services.

**Keywords**—blockchain, smart contracts, integrated energy services, trading mechanisms

## I. INTRODUCTION

Under the background of energy Internet and new generation digital technology, integrated energy service is a new form of business that provides users with efficient and intelligent integrated energy supply and related value-added services through the full cross-border integration of energy, information and communication technologies. Integrated energy services will break the traditional model of separate planning, design and operation of different energy varieties, and realize the coordination between "electricity, heat, cold, gas and water" energy varieties horizontally and "source, network, charge, storage and use" energy supply links vertically, as well as the interaction between the production side and the consumption side.

With the rise of distributed energy resources with many types and wide quantities, the number, scale and information data of transactions increase accordingly. Centralized decision-making method will make the operation cost of transaction centers become higher and the time consumption increase. If the transaction center is attacked by hackers, the security of the transaction and the privacy of the participants cannot be guaranteed. In this context, the distributed trading pattern characterized by large number of participants and small transaction volume has gradually become a trend. In the process of distributed transaction decision-making, there is a lack of central supervision mechanism[1]. How to verify and verify the identities of both parties to ensure the security of transactions is an urgent problem to be solved.

As a kind of decentralized distributed billing system, block chain technology can be solved with the help of cryptography theory in the process of trade dispute,

effectively solve the problem of information asymmetry in the process of trading, block chain technology has the trust the cost is low, the information not tamper with the characteristics of its application to integrated energy trading become a kind of research trend. The technical features of blockchain, such as security and credibility, openness and transparency, and collective maintenance, can meet the needs of integrated energy market transactions, and are of great significance for consuming distributed energy, promoting the development of integrated energy transaction mode, reducing transaction costs, and improving the level of demand-side management[2].

Blockchain can be likened to a distributed database technology. By maintaining the chain structure of data blocks, it can maintain continuously growing and non-tamper data records. It has the characteristics of decentralization, collective maintenance, intelligent contract, security and trust, etc. As a typical programmable technology, intelligent contract can write the process of transaction execution into an automatic programmable language, and enforce the pre-embedded command through the code to ensure the automaticity and integrity of transaction execution.

Currently, blockchain technology can be divided into three categories according to the degree of decentralization, including public blockchain, alliance blockchain, and private blockchain. In the public chain, each participant on the chain can send a transaction, and each individual can participate in the entire consensus process[3]. However, the energy consumption of public chain transaction is large and uncontrollable. The private chain only USES the blockchain general ledger technology for accounting and is generally only used within an enterprise or organization. Only part of the alliance blockchain built by multiple organizations participates in the consensus process, while the rest of the nodes only participate in the transaction process[4]. Therefore, the alliance blockchain has the characteristics of partial decentralization. It has both the privacy of the private chain and the decentralized thinking of the public chain.

At present, the blockchain technology has been preliminarily applied in the field of energy. The TransActive Grid project in Brooklyn connects photovoltaic transactions with a blockchain, allowing it to manage recorded transactions with little involvement of personnel[5]. The ultimate goal of Grid Singularity is to create a blockchain platform for energy systems that would host all types of transactions on the Grid[6]. Southeast University proposed Helios, a solar power distribution system run on the ethereum blockchain and controlled by intelligent contracts,

to enable micro-grid consumers to produce, consume and trade energy[7].

With the development of integrated energy services, the number, scale and information data of multi-energy transactions increase sharply, the time, human and material costs of energy transactions become higher, and users have higher requirements for the fairness, transparency and privacy of transactions. Based on the intelligent contract technology of consortium blockchain, this study explores the integrated energy trading process and application mechanism, and conducts research on the business model of energy trading and the application of smart contract under the integrated energy service.

Block chain technology is the use of block chain to verify the data structure and data storage and use of distributed node consensus algorithm to generate and update the data, the use of cryptography way to ensure the security of data transmission and access, the use of automated script code intelligent contracts to programming and operating data of a new kind of distributed infrastructure and computing paradigm. In block chain system, every once in a while, the participation main body the transaction data will be packaged into a block of data, data blocks according to the time sequence arrangement, form data blocks, chain, chain, each players have the same data and unable to tamper with, modify any information only after the consent of the subject of conventional scale and only add new information, unable to delete or modify the old information, so as to realize information sharing between the players and more consistent decisions, make sure that the main body status and trading information between the main body of the tamper-resistant, open and transparent. These features guarantee the "Honesty" and "Transparency" of the blockchain and lay the foundation for creating trust in the blockchain. The huge application scenarios of blockchain are basically based on blockchain to solve the problem of information asymmetry and realize the cooperative trust and concerted action among multiple subjects.

## II. SYSTEM DESCRIPTION

### A. Blockchain

Blockchain technology is the use of block chain to verify the data structure and data storage and use of distributed node consensus algorithm to generate and update the data, the use of cryptography way to ensure the security of data transmission and access, the use of automated script code intelligent contracts to programming and operating data of a new kind of distributed infrastructure and computing paradigm. Simple speaking, in the block chain system, every once in a while, the transaction data of each participation main body will be packaged into a block of data, data blocks according to the time sequence arrangement, form data blocks, each players have the same data and unable to tamper with, modify any information only after the consent of the subject of conventional scale and only add new information, unable to delete or modify the old information, so as to realize information sharing between the players and more consistent decisions, make sure that the main body status and trading information between the main body of the tamper-resistant, open and transparent.

#### (1)Decentralization

Blockchain is a distributed data storage structure with no central node. All nodes store all the same block information and realize complete decentralization. For special application scenarios, the weakly centralized management node can be appropriately adopted, that is, the central node does not affect the operation of the entire block chain structure, such as the weakly centralized supervision mechanism. From the perspective of security, the central node in the weakly centralized structure should satisfy that it does not pose a threat to the security of the block chain or to the privacy of users.

#### (2)Untamability

Blockchain trading information stored in each article has a corresponding Hash value, of each record generated binary tree of Merkle Hash value as the leaf node, Merkle root node of the tree (Hash value) stored in the section size of the block, block head in addition to the current block Merkle root node of the tree, but also save the time stamp and former a block identifier (Hash pointer) to form a chain structure. Therefore, to tamper with a record in a blockchain, it is necessary to modify not only the Hash value of this block, but also the Hash value of all subsequent blocks, or to generate a new blockchain structure, making the new chain longer than the original chain.

#### (3)Unforgeability

The transaction data stored in the blockchain contains not only Hash values, but also the signatures of both parties and the verifier. The signature is non-forgery and therefore non-forgery.

#### (4)Verifiability

Verifiability refers to the verifiability of the data source. The generation and input and output of electronic money in every transaction can be verified. The blockchain structure will not add electronic money out of thin air. Take Bitcoin as an example. The input of each transaction is the output of the previous transaction, and the output of each transaction is the input of the next transaction, namely the traceability of the transaction. In addition to verification of the source, there is also verification of the transaction amount, that is, verification of the correctness of the amount to ensure that every piece of money in the transaction is reliable. At present, in order to ensure the privacy of users, many electronic currencies can cut off the traceability of the amount as far as possible through the technology of mixed currency, ring signature, zero-knowledge proof and so on in the case of data verification.

#### (5)Anonymity

Anonymity in blockchain is actually a pseudo-anonymity. The blockchain USES pseudonyms to sever links between accounts and real identities. For example, a series of Hash operations are performed on the user's public key, and the fixed length Hash value obtained is used as the corresponding electronic account. As a matter of fact, with the increase of usage times, many transaction behaviors of the account can be analyzed through data analysis, such as which accounts are frequently traded with, the amount of transaction, etc., and even can be connected with the real identity in reality.

### B. Smart contract

Smart contracts are event-driven, dynamic, multi-recognized programs that run on the blockchain and can automatically process assets according to preset conditions. The biggest advantage of intelligent contracts is to replace artificial arbitration and contract enforcement with program algorithms. In essence, a contract is a program, but unlike traditional IT systems, an intelligent contract inherits three features of a blockchain: data transparency, non-tampering, and permanent operation[8]. Intelligent contracts based on blockchain technology can not only give play to the advantages of smart contracts in terms of cost efficiency, but also avoid the interference of malicious behaviors to the normal execution of contracts. The smart contract is written into the blockchain in the form of digitalization, and the characteristics of the blockchain technology guarantee the storage, reading and execution. The whole process is transparent and traceable, and cannot be tampered with. At the same time, a set of state machine system is constructed by the consensus algorithm inherent in the blockchain, so that the smart contract can run efficiently.

In the blockchain system, due to its information untamability and information symmetry, if one party of the contract tampers with the terms alone, it will be immediately detected by the system mechanism and its modification will be traced back. Finally, it will be implemented in accordance with the initial contract guarantee, thus preventing possible risks. In such a "de-trusted" environment, smart contracts have the potential to be widely applicable[9]. Smart contracts are deployed on ethereum, a distributed platform that runs on "Ethereum virtual Machines", a distributed computing network made up of all the devices running Ethernet nodes[10]. The operation mode of blockchain smart contract is shown in the figure 1.

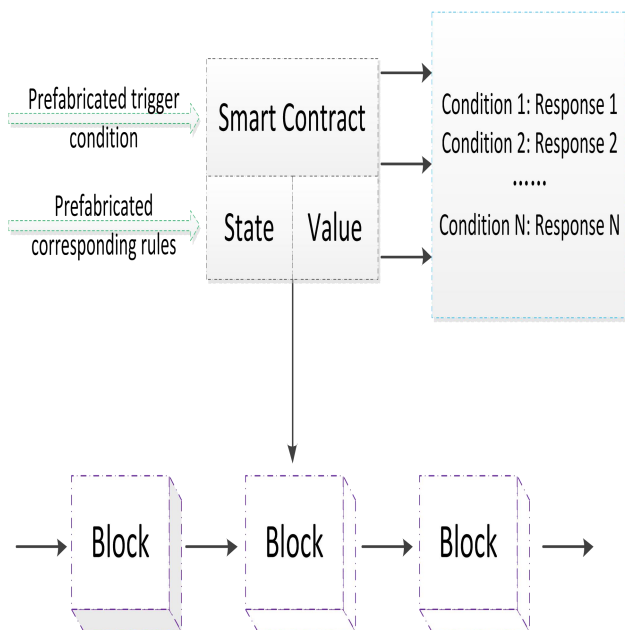


Fig.1. Overall diagram of intelligent contract

### C. Integrated energy trading process based on smart contracts of blockchain

In the process of integrated energy trading based on blockchain, the owners and users of integrated energy can directly conduct point-to-point transactions, in which the process of transaction processing is completely automated.

Take the transaction between integrated energy owner A and user B as an example. The process of integrated energy transaction based on block chain is shown in the figure 2.

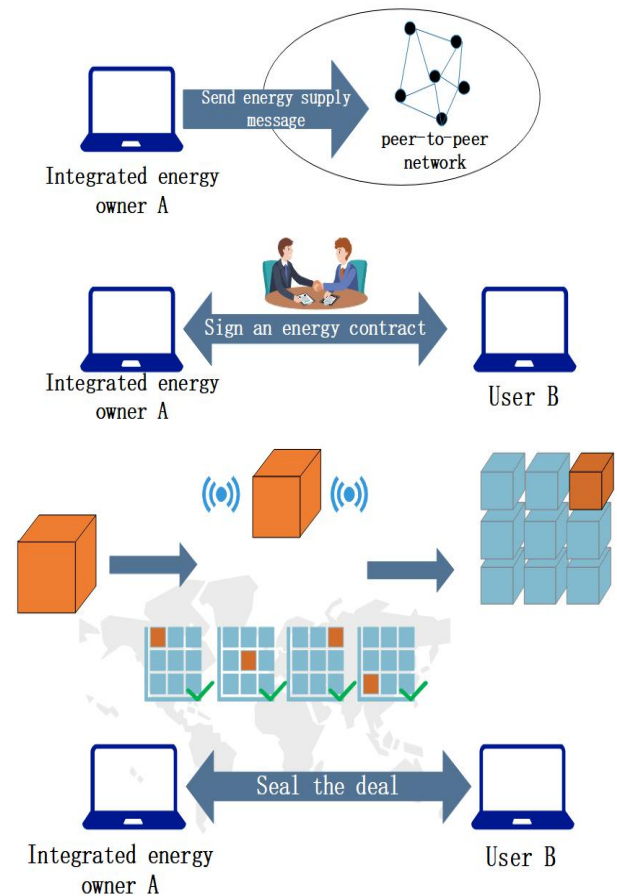


Fig.2. Integrated energy trading model based on smart contracts of blockchain

The specific steps of the transaction process are as follows:

(1) Integrated energy owner A publishes sales information on the platform through the client APP, and all nodes will receive this information;

(2) User B intends to purchase A variety of energy sources sold by integrated energy owner A, and transmits the purchase information to integrated energy owner A;

(3) Integrated energy owner A signs the energy purchase contract with user B;

(4) According to the time specified in the contract, at A certain time, Integrated Energy Owner A will make the transaction sheet containing the transaction information and its digital signature, and then broadcast the transaction to the network;

(5) All trading nodes receive trading information and obtain the right to create trading blocks by solving problems. After a node successfully solves the problem, a trading block is created and timestamped, and then broadcast to the network.

(6) All nodes in the network verify whether the transaction block is correct. After the verification is passed, the block will be added to the local block chain of the node to form a legal block chain;



(7) At this time, integrated energy owner A and user B complete the transaction, and user B pays integrated energy owner A with the digital currency to purchase energy, while integrated energy owner A sells energy to user B.

Compared with the traditional contracts, the integrated energy trading process based on the blockchain smart contract is automated, which requires no personnel to participate in the whole process, reduces the manual reconciliation process, improves the efficiency of business settlement and clearing, improves the user's energy use experience and enhances the user's stickiness.

#### D. Measurement certification

Measurement certification is the basis of smart contract of blockchain in integrated energy transaction settlement, and measurement data must be true and reliable. The blockchain transaction data is not only secure and transparent, not easy to tamper with and easy to track, but can be applied to the measurement and certification process of integrated energy transactions.

The specific steps are as follows:

- (1) Energy trading platform based on block chain and smart meter data docking;
- (2) Integrated energy owner A and user B conduct energy transactions, and the smart meter feeds back the actual energy transaction data to the blockchain trading platform;
- (3) The blockchain trading platform has a unique trading ID and a timestamp;
- (4) This transaction record is added to the measurement certification block chain, which cannot be tampered with and provides basic data for settlement and payment;
- (5) Users can trace any historical energy transaction.

### III. MAIN RESEARCH CONTENTS

#### A. Smart contract application mechanism

Integrated energy owners and users no longer need to sign paper purchase contracts. Both parties of the transaction can use codes to write intelligent electricity purchase contracts, making the contracts into computer execution programs. If the agreed conditions are met, the contracts can be automatically executed. Blockchain has the technical features to ensure that the entire process of storage, reading, and execution is transparent, traceable, tamper-proof, and efficient. Intelligent power purchase contract not only has advantages in cost and efficiency, but also can avoid the human malicious behavior to interfere with the normal execution of the contract. The specific application method is shown in the figure 3.

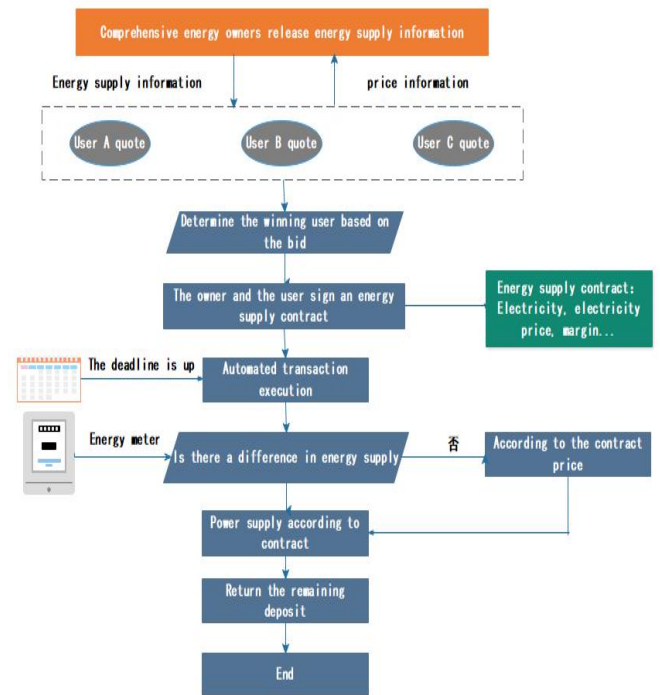


Fig.3. Integrated energy trading process based on smart contracts of blockchain

The specific steps are as follows:

- (1) A integrated energy owner publicly releases an energy selling information in a peer-to-peer network, including information such as energy selling, intended selling price, etc.;
- (2) The user makes a voluntary quotation to the owner according to his actual situation. The quotation information includes purchase energy, intended purchase price, etc., and the quotation information shall be kept confidential;
- (3) Integrated energy owner according to the quote information of each user to determine one or several party b in the contract, with the corresponding user intelligence can purchase contracts, including prescribed energy trading volume, trading energy price, contract execution time, deposit, etc., the owner and the user needs to be set aside a certain margin in their account, after signing the contract, deposit account freeze.
- (4) When the specified time limit expires, the intelligent energy purchase contract will be executed automatically;

#### B. Energy Package

The previous section has discussed the application mechanism of integrated energy intelligent purchase contract based on block chain. The basic transaction process has been clarified. In view of the multi-energy supply characteristics of integrated energy services, intelligent contract can completely provide safe, stable and efficient multi-energy transactions.

Huadian industrial park is an integrated office building project which invested and developed by Huadian Science and Technology Group. The total construction area is 250,000 m<sup>2</sup>, including 170,000 m<sup>2</sup> above ground and 80,000 m<sup>2</sup> underground. There are a total of nine office buildings

consist of commercial office buildings, hotels, computer rooms and charging piles so far, as shown in Table I.

Huadian industrial park integrated energy service projects, for example, at present park inside the hotel rooms, offices, stores, offices, data such as much variety level load, by gas distributed energy station in the park for the user to cold, heat, electricity, hot water and other energy supplies. At present, the basic mode of energy transaction is electricity charging by meter, cold and hot charging by area, and the charging mode is unified for all users. It is hard to avoid the difference of economy and comfort between different users due to the different characteristics of energy use.

The energy station of Huadian industrial park can provide users with a variety of energy, among which the maximum power supply capacity is 6.698MW, the cooling capacity is 16.36MW, the heating capacity is 11.704MW, and the domestic hot water supply capacity is 3.5MW, as shown in Table II.

TABLE I. LOAD COMPOSITION OF HUADIAN INDUSTRIAL PARK

category	Office	hotel	commercial	garage	other
proportion	53.7%	13.7%	4.9%	23.7%	4%

TABLE II. ENERGY STATION SUPPLY CAPACITY

Types of energy	Maximum electricity capacity	Maximum cooling capacity	Maximum heat capacity	Maximum hot water capacity
Supply capacity maximum	6.698MW	16.36MW	11.704MW	3.5MW

In line with integrated energy services, it provides users with high-quality energy, improves users' energy experience, and achieves the goal of economical and efficient use of energy. It also explores the business model of energy trading under intelligent contracts of blockchain. According to users' energy needs, a variety of energy combinations can be combined to launch the "Energy Package", as shown in Figure 4.

(1) Power load: charge according to the meter, pay in advance, and step electricity price according to the amount paid in advance.

(2) Cooling and heating load of air conditioning: multi-option charging mode is implemented. Users can choose to charge according to area or flow, and charge according to time. The longer the service time (annual payment, quarterly payment, monthly payment, etc.) is paid in advance, the lower the cost.

(3) Domestic hot water: charge according to the meter, pay in advance, and step price according to the amount paid in advance.

The charging and trading modes can be written into the program according to the intelligent contract mechanism, or adjusted according to other situations. When the contract is signed by both parties, the performance conditions will be triggered, and the contract will be executed automatically.

No personnel will be required to participate in the whole process, which reduces the manual reconciliation process and improves the efficiency of business settlement and settlement.

At the same time, this kind of energy trading business model provides users with the opportunity to choose, according to their own energy-using characteristics, each needs, improve user experience, enhance user stickiness.

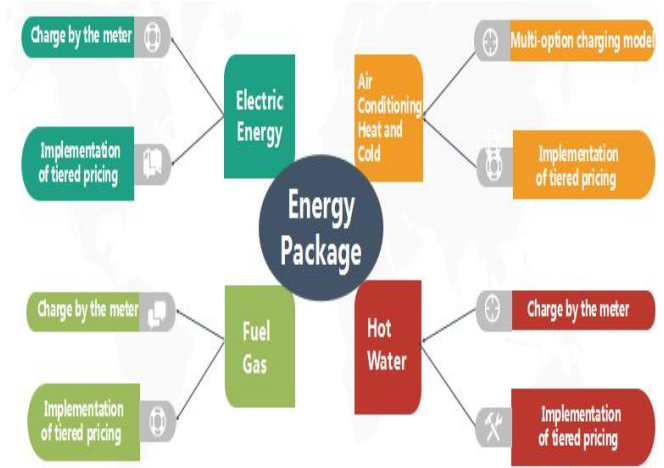


Fig.4. Overall diagram of "Energy Package"

#### IV. PROJECT ADVANCEMENT AND EXPECTED RESULTS

##### A. Technical advantages

(1) Compared with the traditional contract, the biggest characteristic and advantage of intelligent contract is that it solves the problem of "credit". Before the traditional contract is concluded, participants should first understand the credit background of all parties to select a suitable target. The stage after the contract is concluded depends on the honesty and credit of all parties, or a third party (such as Alipay) is introduced to guarantee the performance of the contract.

(2) Intelligent contract because the resources on the chain are real and transparent, the content of the contract cannot be changed after it is determined, and the execution does not depend on any additional operation. Finally, "anonymous credit" becomes a reality. There is no need to conduct credit investigation before the conclusion of the contract, and no need to perform guarantee by a third party after the conclusion of the contract. Thus, transaction costs are greatly reduced and transaction efficiency is greatly improved.

(3) The history of smart contracts can be traced back and the cost of tampering with them is high.

(4) Decentralized intelligent contracts that do not rely on third parties to execute contracts. Thus, the potential benefits of smart contracts include lower costs for signing, enforcing and monitoring contracts; Thus, for many contracts associated with low-value transactions, this is a significant reduction in labor costs. The whole process of contract validation and execution is accelerated by direct transactions between users.

(5) Intelligent contract is not prone to power failure, node failure, flood and fire and other problems. When smart contracts are kept on a blockchain distributed ledger, there is no risk of misplacing or losing them.

### B. Project innovation

As an emerging technology, blockchain has the technical characteristics of "decentralization, openness and transparency, security and reliability, and transaction traceability", etc. The development of blockchain has been widely concerned by the society, and its application in the field of energy has begun to be preliminarily explored.

In the context of integrated energy services, this study explored the process and application mechanism of integrated energy trading based on the intelligent contract technology of block chain, and demonstrated the integrated energy service transformation project in the industrial park according to the research situation.

(1)Research and use the block chain intelligent contract technology to explore the integrated energy trading process and application mechanism, which is more stable, safe and efficient compared with the traditional contract and greatly reduces the labor cost.

(2)Studied the business model of energy transaction under integrated energy service, put forward the business model of multi-energy transaction and applied intelligent contract to improve users' energy use experience and enhance user stickiness.

(3)The application mechanism of measurement and certification of blockchain intelligent contract in integrated energy transaction is studied to improve the reliability of measurement and certification of integrated energy transaction.

(4)Through the demonstration and verification of integrated energy intelligent contract trading mechanism of industrial park integrated energy service project, the application prospect of block chain technology in the field of integrated energy service is prospected.

### C. Economic benefits

(1)Save labor costs for trading staff

(2)Save the time cost of multiple negotiation and reconciliation between the two parties, and reduce the running work of transaction process.

(3)Smart contracts significantly reduce performance costs, save performance fees, and other associated bank borrowing costs.

### D. Social benefits

(1)Because of the implementation of online trading, carbon emission reduction has been achieved and the goal of environmental protection and efficiency has been achieved.

(2)To meet the needs of users for intelligent use of energy, to avoid energy waste, to guide behavioral energy conservation with technology.

(3)It promotes the innovation of the application scenario of blockchain technology and realizes the demonstration of

the project, which has reference significance for the research and application of new technologies.

## V. CONCLUSION

Under the background of integrated energy services, this study based on smart contract, blockchain achieve energy producers and energy consumers point-to-point energy trading, intelligence is proposed based on blockchain contract integrated energy transaction structure, transaction process and the business model application, introduced the "Energy Package" trading mode, expand the blockchain technology application scenarios, blockchain technology for the future research and application in the field of integrated energy services.

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